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Soil Guideline Values for phenol in soil

Science Report SC050021 / Phenol SGV

This technical note is one in a series that describe Soil Guideline Values (SGVs) for individual, or groups of similar, chemicals to assist in the assessment of risks from land contamination.

SGVs are an example of generic assessment criteria (Defra and Environment Agency, 2004) and can be used in the preliminary evaluation of the risk to human health from long-term exposure to chemicals in soil. Specifically, this note provides SGVs for phenol. It does not consider other phenolic compounds, including halogenated phenols and alkyl phenols (e.g. nonylphenol), whose toxicity and environmental fate are quite different from phenol itself.

The SGVs and the additional advice found here should be used only in conjunction with the introductory guide to the series entitled *Using Soil Guideline Values* (Environment Agency, 2009a), the framework documents *Updated technical background to the CLEA model* (Environment Agency, 2009b) and *Human health toxicological assessment of contaminants in soil* (Environment Agency, 2009c), and *Contaminants in soil: updated collation of toxicological data and intake values for humans. Phenol* (Environment Agency, 2009d). Supplementary information on phenol is also available (Environment Agency, 2009e).

All notes in the SGV series, the introductory guide and further supplementary information can be downloaded from our website (<http://www.environment-agency.gov.uk/clea>).

Phenol

Phenol (CAS No. 108-95-2) is a naturally occurring monoaromatic hydrocarbon, formed by the substitution of a single hydroxyl group (-OH) on a benzene ring. It is also known as benzenol, carbolic acid, monohydroxybenzene, phenic acid and phenyl alcohol (ECB, 2006; MERCK, 2006; ATSDR, 2008).

Pure phenol is a colourless to light pink crystalline solid at room temperature, though it readily absorbs moisture and liquifies at a moisture content of eight per cent by weight (Streitwieser and Heathcock, 1981; ECB, 2006). It is water soluble and a weak acid, with a reported disassociation constant (pKa) of 9.89 at 20°C (ECB, 2006). Phenol is moderately volatile and has a

characteristic sweet and acrid odour (MERCK, 2006; ATSDR, 2008). It also has an unpleasantly sharp burning taste, which taints drinking water at concentrations as low as 150 µg L⁻¹ (ECB, 2006; MERCK, 2006). Phenol has corrosive properties and is acknowledged to be a powerful skin irritant in humans (Streitwieser and Heathcock, 1981; ECB, 2006; MERCK, 2006; Environment Agency, 2009d).

The chemical properties of phenol are strongly influenced by its resonance stabilisation and the formation of the phenolate anion (Streitwieser and Heathcock, 1981; IPCS, 1994). Phenol is sensitive to oxidising agents, forming various compounds including dihydroxy- and trihydroxybenzenes and quinones, and is a suitable antioxidant (IPCS, 1994). It also undergoes electrophilic substitution reactions including halogenation, nitrosation and sulfonation (Streitwieser and Heathcock, 1981; IPCS, 1994).

Although phenol forms naturally during the decomposition of organic materials and is a constituent of coal tar, its presence in the environment is primarily the consequence of human activities (IPCS, 1994). It is most commonly manufactured by the oxidation of cumene, although it can also be made by the oxidation of toluene, the vapour phase hydrolysis of chlorobenzene, or by the distillation of coal tars or petroleum (ECB, 2006; ATSDR, 2008).

Recent estimates have suggested annual production of phenol in the European Union is over 1.8 million tonnes of which around 0.3 million tonnes are exported to non-EU member states (ECB, 2006). Currently, phenol is used primarily in the manufacture of bisphenol A and phenolic resins, although it is also important in producing other organic chemicals including alkyl phenols, caprolactam, xlenols, nitrophenols, diphenyl ethers and halogenated phenols (ECB, 2006; ATSDR, 2008). It is used in smaller quantities in the production of cosmetics, adhesives, paints, lacquers and varnishes, and in solvents (ECB, 2006).

Phenol was widely used in the 19th century as an antiseptic and local anaesthetic, but its potential to cause tissue irritation led to a reduction in its use (IPCS, 1994; ATSDR, 2008). It is used in a limited number of medicines today including antiseptics, lotions, salves and ointments (IPCS, 1994; ECB, 2006). It has also been used as a general disinfectant either in solution or mixed with slaked lime, but this appears to be in decline in European countries (ECB, 2006; MERCK, 2006; ATSDR, 2008).

Potential harm to human health

The principles behind the selection of Health Criteria Values (HCVs), and the definition of concepts and terms used, are outlined in *Human health toxicological assessment of contaminants in soil* (Environment Agency, 2009c). Specific information on the toxicity of phenol has been reviewed in *Contaminants in soil: updated collation of toxicological data and intake values for humans. Phenol* (Environment Agency, 2009d) and only a brief summary is presented here.

Phenol is considered to be a somatic cell mutagen by all exposure routes (Environment Agency, 2009d). Although this mutagenic activity appears to have a threshold via the oral route, possibly because of phenol's rapid metabolism and detoxification in the liver,

approach to risk assessment via the dermal and inhalation pathways.

Phenol has been shown to cause liver and kidney damage, neurotoxic effects and developmental toxicity in laboratory animals (Environment Agency, 2009d). In experimental studies, phenol has exhibited a higher degree of toxicity when given by stomach tube than when administered in drinking water. The inhalation toxicity database is very limited, though it does appear that phenol is more potent when inhaled than when ingested.

Health Criteria Values (HCVs) for phenol are summarised in Table 1.

The oral tolerable daily intake (TDI_{oral}), which is based on the current recommendation of the UK Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT), is based on a two-generation reproductive and developmental toxicity study in rats (Environment Agency, 2009d).

The inhalation tolerable daily intake (TDI_{inh}), based on limited occupational epidemiology data, applies to non-mutagenic toxicological endpoints only (Environment Agency, 2009d). There is currently insufficient evidence to establish an Index Dose for the potential non-threshold mutagenic effects of inhaled phenol.

The adult inhalation mean daily intake (MDI_{inh}) for phenol is estimated at $40 \mu\text{g day}^{-1}$. The adult oral mean daily intake (MDI_{oral}) for phenol from food and water combined is approximately $350 \mu\text{g day}^{-1}$ (Environment Agency, 2009d).

Phenol can potentially be absorbed through the skin in toxic amounts, but no authoritative assessments of dermal toxicity have been identified (Environment Agency, 2009d). In view of the reduced toxicity observed via the oral route, following first-pass metabolism, it would seem most appropriate to compare dermal exposure with the TDI_{inh} .

Since both ingested and inhaled phenol causes similar threshold systemic toxic effects, this should be considered in an assessment where exposure occurs via both routes (Environment Agency, 2009d).

In addition to the potential health effects arising from long term exposure, phenol also possesses corrosive properties and it is acknowledged to be a powerful skin irritant in humans (ECB, 2006; Environment Agency, 2009d). Local effects following skin contact include inflammation, dermatitis and reddening of the skin, which often results in white or brown necrotic lesions (IPCS, 1994; HPA, 2007). It also has a local anaesthetic effect which means that burns caused by phenol may not be felt immediately.

Most reports of the corrosive and irritant effect of phenol on skin have involved application of aqueous solutions. At concentrations of ten per cent by weight such effects are regularly reported but irritation and skin necrosis has also been reported after contact with solutions as dilute

Table 1

Recommended Health Criteria Values and estimated background adult intakes for phenol (Environment Agency, 2009d).

Parameter	Phenol
$TDI_{oral}, \mu\text{g kg}^{-1} \text{ bw day}^{-1}$	700
$MDI_{oral}, \mu\text{g day}^{-1}$	350
$TDI_{inh}, \mu\text{g kg}^{-1} \text{ bw day}^{-1}$	10
$MDI_{inh}, \mu\text{g day}^{-1}$	40

Notes:

bw = bodyweight

TDI = tolerable daily intake

MDI = mean daily intake

there is insufficient evidence to support a threshold

Ionising potential of phenol in soil-water systems

The table below illustrates the fraction of ionised phenol as a proportion of total dissolved phenol at different pH values, assuming a disassociation constant (pKa) of 9.89 at 20°C (ECB, 2006; Environment Agency, 2006).

Soil-water system pH	Proportion ionised (%)
5	< 0.1
6	< 0.1
7	0.1
8	1.3
9	11.4

as one per cent by weight (Sullivan and Krieger, 2001; ECB, 2006; HPA, 2007). Importantly, it is noted that phenol concentration is more critical than volume with respect to local response (Kania, 1981).

Exposure assessment

Occurrence in soil

Most soils will contain very little phenol from natural processes (ECB, 2006). Phenol is formed during the natural decomposition of organic matter and is a major metabolite of benzene (ATSDR, 2008). It has also been found in animal manures, which are a small but significant component of atmospheric emissions, and in human urine and faeces (IPCS, 1994; ECB, 2006). Phenol is formed during combustion of organic materials including wood, and elevated levels have been detected as a result of forest fires (IPCS, 1994; ECB, 2006; ATSDR, 2008).

Anthropogenic activity is the main source of phenol in soil (IPCS, 1994; ECB, 2006; ATSDR, 2008). It is released to the atmosphere during the production and use of phenolic resins, and is formed as a combustion by-product in emissions from vehicle exhausts, waste incinerators and coal-fired power stations (IPCS, 1994; ECB, 2006; ATSDR, 2008). It is released into wastewater following industrial production and use, as a by-product from petroleum refining and paper pulp manufacturing facilities, and in human sewage (ECB, 2006). The major releases to soil include the spreading of animal manures and sewage sludge, and the historical manufacture of coal gas and coke (ICRCL, 1986; DoE, 1995; ECB, 2006).

A review of the literature identified no data on background levels of phenol in UK soils. ECB (2006) estimated a regional background soil concentration of phenol to be around $0.6 \mu\text{g kg}^{-1}$, based on all releases of phenol to the environment but not including the application of sewage sludge to soil or soil located close to a point source.

The highest concentrations of phenol are expected to be found in soils contaminated with coal tars and other wastes from former gasworks (ICRCL, 1986; DoE,

1995). Bennett *et al.* (1999) reported phenol concentrations up to 40 mg L^{-1} in 150 water samples collected from different gasworks.

Behaviour in the soil environment

Recommended values for chemical data used in the exposure modelling of phenol are shown in Table 4. Further information about the selection of chemical properties can be found in Environment Agency (2008). *Supplementary information for the derivation of SGV for phenol* (Environment Agency, 2009e) provides additional information about the review and recommendations for the soil-to-plant concentration factors for phenol.

Phenol is considered by most authoritative expert groups to be mobile in the environment and to partition preferentially to the water compartment (IPCS, 1994; ECB, 2006; ATSDR, 2008). Based on its physical-chemical properties, it will be weakly bound by soil organic matter and therefore will leach readily from soil to ground and surface water (ECB, 2006; Environment Agency, 2008).

Khan and Anjaneyulu (2005) found that organic matter content was the most important soil component controlling adsorption potential in three different soils followed by clay mineral content. Wu *et al.* (2008) found that phenol was weakly adsorbed to iron oxides, with the highest adsorption between pH 7–8 and close to the iron oxides point of zero charge.

Phenol is a weak acid with a pKa close to 10 (ECB, 2006; ATSDR, 2008). Therefore, under the pH conditions found in most soils, phenol will not be appreciably ionised (see box). Although slightly volatile in dry soils, its air–water partition coefficient indicates that phenol will not volatilise readily from water to air and therefore the potential for vapour release from damp or wet soils is low (ECB, 2006; ATSDR, 2008; Environment Agency, 2008).

There is general agreement that phenol can be rapidly biodegraded in soil under both aerobic and anaerobic conditions (ECB, 2006; ATSDR, 2008). However, phenol does persist in contaminated soils and coal tar wastes, suggesting that optimal degradation conditions are not always achieved, primarily because of its ecotoxicity. Welp and Brümmer (1999) noted that the toxic effect of phenol on soil microbial activity varied greatly between soils and depended on mineral composition, organic content and pH. Mrozik *et al.* (2008) observed phenol toxicity to phenol-degrading *Pseudomonas stutzeri* was highest in soils with low organic matter content and consequently high phenol availability. Conversely, IPCS (1994) noted that a reduction in the biodegradation of phenol in soil may be due to its increased sorption. Environment Agency (2002) commented that there was no clear relationship between aqueous phenol concentrations in groundwater and biodegradation rate, and that “significant inhibition of biodegradation activity takes place at elevated dissolved concentrations in groundwater”.

There are very little data on the uptake of phenol by higher plants (Environment Agency, 2009e). With an octanol–water partition coefficient ($\log K_{ow}$) close to 1.5, the potential for uptake and translocation of phenol by plants is relatively high (Environment Agency, 2006). This view is supported by several authoritative organisations, although the overall bioaccumulation potential for phenol is likely to be low because of its extensive and rapid metabolism (ECB, 2006; ATSDR, 2008).

Although the dermal pathway is considered to be a highly significant route of exposure for phenol, both occupationally and from waste sites, there appear to have been a limited number of studies of dermal uptake from soil (Skowronski *et al.*, 1994; Abdel-Rahman *et al.*, 2006; ATSDR, 2008). Skowronski *et al.* (1994) studied the dermal absorption of phenol alone and from freshly spiked soils using patches of pig skin *in vitro*. Maximum phenol penetration occurred between two and four hours after contact. Overall penetration after 12 hours was 53.6 per cent for phenol alone, 30.9 per cent for phenol in the sandy soil and 24.7 per cent for phenol in the clay soil (Skowronski *et al.*, 1994). Abdel-Rahman *et al.* (2006) studied the impact of aging time on the dermal absorption of phenol using the same soils reported by Skowronski *et al.* (1994). After six months, dermal absorption was reduced to eight per cent for the sandy soil and 17 per cent for the clay soil (Abdel-Rahman *et al.*, 2006).

An ABS_d^1 of 0.3 has been used for phenol in the derivation of SGV. This is based on the highest penetration observed for phenol applied freshly to soil after a 12-hour contact time (Skowronski *et al.*, 1994). This value is considered to be appropriately protective in the context of historical land contamination, as phenol in soil appears to become less, rather than more, dermally available over time.

A review of the literature found no data that could be used to provide a generalised soil-to-dust transport factor for phenol. In the absence of a contaminant-specific soil-to-dust transport factor, the default value of 0.5 g g^{-1} dry weight (DW) has been used.

Soil Guideline Values

Soil Guideline Values (SGVs) for phenol are presented according to land use in Table 2. The SGVs apply only to phenol and not to phenolic compounds in general. For residential and allotment land uses, SGVs are based on estimates representative of exposure of young children because they are generally more likely to have higher exposures to soil contaminants. Further information on the default exposure assumptions used in the derivation of SGVs can be found in *Updated technical background to the CLEA model* (Environment Agency, 2009b).

Table 2

The Soil Guideline Values for phenol presented in this table should only be used in conjunction with the information contained in this briefing note and with an understanding of the exposure and toxicological assumptions contained in *Updated technical background to the CLEA model* (Environment Agency, 2009b), *Human health toxicological assessment of contaminants in soil* (Environment Agency, 2009c) and *Contaminants in soil: updated collation of toxicological data and intake values for humans. Phenol* (Environment Agency, 2009d).

Land use	Soil Guideline Value (mg kg^{-1} DW) ^{1,2}
	Phenol
Residential	420
Allotment	280
Commercial ³	3,200 (38,000)

Notes: ¹ Figures are rounded to one or two significant figures
² Based on a sandy loam soil as defined in Environment Agency (2009b) and 6% soil organic matter (SOM)
³ Based on a threshold protective of direct skin contact with phenol (guideline in brackets based on health effects following long term exposure provided for illustration only).

Analytical limits of detection² for phenol depend on the analytical technique used and range from 0.001 to 4.0 mg kg^{-1} DW, with limits of quantification³ ranging from 0.005 to 20 mg kg^{-1} DW. Limits of detection and quantification can vary due to the sample matrix and the range, sensitivity and set-up of the instrumentation being used. MCERTS⁴ accredited analytical methods for phenol in soil are available.

Further risk evaluation

The SGVs for phenol are based on a consideration of the total systemic exposure via the oral, dermal and inhalation routes. In view of the reduced toxicity observed via the oral route (following first pass metabolism) dermal exposure has been compared with the TDI_{inh} (Environment Agency, 2009d).

In the case of the commercial land use scenario, however, a threshold concentration in soil considered to be protective of the corrosive and skin irritant properties of direct contact with phenol is lower than the corresponding assessment criterion based on long term exposure (see below for further discussion). Therefore, for the commercial land use, the SGV is based on direct bodily contact with phenol contaminated soils.

Table 3 presents the estimated contribution via each exposure pathway to total exposure at a soil

¹ Dermal absorption fraction

² The amount of a substance that can be detected, but not quantitatively measured

³ Amount present of a substance that can be quantitatively measured

⁴ Environment Agency's Monitoring Certification Scheme

concentration equal to the SGV for the residential and allotment land use scenarios. The ratios of oral and inhalation/dermal exposure to the relevant HCV at a soil concentration equal to the SGV are also reported. The data show that:

- consumption of homegrown produce and attached soil makes the greatest contribution to total exposure for the residential and allotment land use scenarios;
- inhalation exposure from soil contamination makes a small contribution to total exposure for the residential and allotment land use scenarios;
- background exposure is a significant contributor to total exposure for the residential land use scenario;
- dermal exposure drives the risk to health from soil contamination for the residential land use scenario because of the significantly lower potential threshold of toxicity for phenol via the non-oral route (the TDI_{inh} is 70 times lower than the TDI_{oral});
- consumption of homegrown produce drives the risk for the allotment land use scenario because of the dominance of this exposure pathway;
- background exposure via the inhalation pathway makes a significant contribution to risk for the residential land use scenario, though its contribution to total exposure is small.

In addition to the potential health effects arising from long term exposure, phenol also possesses corrosive properties and it is acknowledged to be a powerful skin irritant in humans (ECB, 2006; Environment Agency, 2009d).

No information has been identified relating to soil concentrations of phenol that may cause corrosive or irritant effects. However, the study of dermal absorption by Skowronski *et al.* (1994) indicated that, following addition of phenol to soil, its dermal availability is reduced by at least 50% and work by Abdel-Rahman *et al.* (2006) demonstrated that this reduction in bioavailability increases with aging. As noted earlier, the critical concentration for skin irritation in humans arising from contact with phenol in aqueous solution appears to be as low as one per by weight (Sullivan and Krieger, 2001; ECB, 2006; HPA, 2007).

At a total soil concentration equal to an assessment criterion based on long term exposure for the commercial land use ($38,000 \text{ mg kg}^{-1} \text{ DW}$), the linear media partitioning model used in the CLEA software estimates the corresponding soil water concentration for phenol to be 12 g L^{-1} or 1.2 per cent by weight. At one per cent soil organic matter and a revised assessment criterion of around $30,000 \text{ mg kg}^{-1} \text{ DW}$, the corresponding soil solution concentration would increase to four per cent by weight. These potential levels of phenol in soil solution would exceed the threshold for dermal effects of one per cent phenol in aqueous solution reported above.

On this basis, we consider it reasonable to establish the SGV for the commercial land use not on the basis of long term exposure but to be protective of direct bodily contact with contaminated soil. Taking into account uncertainty in modelling exposure to phenol, its partitioning behaviour and soil solution concentration at low organic matter contents, it is prudent to assume that a threshold of $3,200 \text{ mg kg}^{-1} \text{ DW}$ should be used to screen contaminated soils for the commercial land use. At this soil concentration, the corresponding soil solution concentration at six per cent SOM is 1 g L^{-1} or 0.1 per cent by weight.⁵

One further consideration is whether at soil concentrations equal to the SGV, there is a risk to health from chemical permeation of water supply pipes. Environment Agency (2000) noted that some low molecular weight hydrocarbons and chlorinated solvents have the potential to permeate some types of plastic pipes, although more polar compounds such as phenol were considered to be of lesser concern.

WRAS (2002) identified phenol as an organic contaminant having the potential to affect and permeate certain types of plastic water pipes and recommended the relatively low soil concentration of $5 \text{ mg kg}^{-1} \text{ DW}$ as a "threshold concentration in soils affecting [pipe] material selection". However, this threshold concentration appears to have been based on the withdrawn ICRCCL 'trigger concentration' for phenol and the Water Regulation Advisory Scheme (WRAS) acknowledge that these values "are not directly relevant to the selection of pipeline materials".

Concerns over the ability of phenol to permeate MDPE (medium density polyethylene) pipework arise from experimental data published by WRc (1990) using concentrated aqueous solutions of phenol. In these studies, phenol was detected after nine weeks exposure, in a layer approximately 2 mm into a 6.25 mm thickness MDPE pipe⁶. The overall conclusion was that phenol permeated at a slow rate and in small quantities. Additionally, compounds absorbed onto soil particles are acknowledged to behave differently to those in aqueous solution or in the vapour phase, further reducing the likelihood of ingress to drinking water through pipework from contaminated land (WRc, 1990). Therefore, there is only a small possibility of significant permeation of certain plastic piping where there is prolonged contact with heavily contaminated soils, including the presence of free phase.

RIVM (1994) proposed a method of estimating pipe permeation, although this is highly uncertain and the assessment will depend on the type of pipework found, water usage and the soil concentration immediately adjacent to the pipe wall. Using this method and soil concentrations equal to the SGV in Table 2, the highest

⁵ At one per cent SOM, the corresponding soil solution concentration would be 0.4 per cent by weight.

⁶ In contrast, toluene, used as a positive control, rapidly permeated polyethylene and transport through the pipe was complete after 1 week exposure.

estimated mean drinking water concentration of $2.2 \mu\text{g L}^{-1}$ (based on a soil concentration of $3,200 \text{ mg kg}^{-1} \text{ DW}$) poses a negligible risk to health and is considerably less than the threshold for taste and odour of $150 \mu\text{g L}^{-1}$ reported in the EU risk assessment for phenol (ECB, 2006).

It is therefore concluded that it is highly unlikely that soil concentrations equal to the SGV will pose a significant additional risk to the drinking water supply. However, where extremely high levels of contamination have been found or are suspected close to buried water services, the risk assessor should consider carefully its implications and, where necessary, investigate the likelihood of contamination of the water supply.

Other site specific factors

The generic conceptual exposure models used to derive SGVs (as described in Environment Agency, 2009b) assume that:

- the source term is infinite;
- the source term is not itself reduced by biological or chemical degradation;
- phenol is present in isolation and not in a mixture with other compounds.

Assessors undertaking a Detailed Quantitative Risk Assessment (DQRA) (Defra and Environment Agency, 2004) may wish to consider the applicability of these assumptions on a site-specific basis. The actual degradation half-life of a chemical in soil is highly site-specific and dependent on a number of influences including soil temperature, oxygen availability, microbial population and the presence of other contaminants.

Phenol is a constituent of coal tar and is associated with other wastes from the manufacture of coal gas and coke. It is therefore highly unusual for phenol to occur in isolation in a contaminated soil, although fate and transport calculations (such as those used by the CLEA model) normally assume single component behaviour. The assessor should consider the effects of other substances on the mobility of phenol as part of a DQRA.

The phytoavailability of phenol to garden produce depends on a number of complex factors. The soil-to-plant concentration factors used in the derivation of the SGVs are calculated from generic algorithms (detailed in Environment Agency, 2009b) for a generic scenario. It should be noted in particular that herbaceous and shrub fruit produce groups have not been modelled in the derivation of SGVs (Environment Agency, 2009b). Further consideration is necessary where these produce groups dominate the total fruit and vegetables consumed from a site.

Although such generic algorithms are based on studies of plant uptake of organic chemicals, they do not take into account the persistence and toxicity of the chemical within the plant tissues. Most authoritative expert evaluations consider that phenol is readily taken up by plants, but that it is unlikely to accumulate there because

it would be readily metabolised (ECB, 2006; ATSDR, 2008).

Assessors undertaking a DQRA could also carry out further investigation (including the sampling and chemical analysis of edible parts of fruits and vegetables) to determine site-specific plant concentration factors and thus ascertain the level of phenol in the edible portions of fruits and vegetables. However, the sampling and chemical analysis of edible parts of fruits and vegetables is unlikely to be an easy task.

Although exposure via dermal contact and vapour intrusion is only a small component of total exposure, these are important risk driver pathways for phenol because of the relative differences between the TDI_{inh} and TDI_{oral} . Further discussion on the uncertainties in estimating dermal exposure and in calculating indoor air concentrations using the Johnson and Ettinger algorithm can be found in Environment Agency (2009b).

It is recognised that the concentration of hydrocarbons within the indoor air may be overestimated using this approach. When the inhalation of indoor air is the risk driving pathway, assessors undertaking a DQRA could carry out further assessment such as soil vapour monitoring. Further guidance and information can be found in CIRIA (in press).

In circumstances where the SGV is exceeded, assessors may wish to adjust for the site-specific measured soil organic matter (SOM) content. A higher SOM will mean that less phenol is available for either plant uptake or to enter indoor air via vapour intrusion. SGVs are based on a SOM content of 6 per cent. At a lower SOM, they may not be sufficiently protective.

Table 3

Contribution to exposure from soil for the relevant pathways as calculated by the CLEA software for the residential and allotment land use scenarios. Commercial scenario data are not provided as the SGV is based on a threshold for direct contact effects.

	ADE to HCV ratios	
	Residential	Allotment
Oral ADE to HCV ratio at SGV	0.20	0.90
Dermal and inhalation ADE to HCV ratio at SGV	0.80	0.10
	Contribution to exposure¹ from soil according to land use (%)	
Exposure pathway	Residential	Allotment
Ingestion of soil and indoor dust ²	1.9	<0.1
Consumption of homegrown produce and attached soil	81.3	96.5
Dermal contact (indoor)	0.1	NA
Dermal contact (outdoor)	2.8	0.1
Inhalation of dust (indoor)	<0.1	NA
Inhalation of dust (outdoor)	<0.1	<0.1
Inhalation of vapour (indoor)	0.8	NA
Inhalation of vapour (outdoor)	<0.1	<0.1
Oral background	11.8	3.1
Inhalation background	1.5	0.1

Notes ¹ Rounded to one decimal place

² Treated as one pathway (see Environment Agency, 2009b)

ADE = Average Daily Exposure

HCV = Health Criteria Value

NA = Not applicable (this exposure pathway is not included in the generic land use)

Table 4
Recommended chemical data for phenol (at 10°C unless stated)

Chemical property	Phenol	
Air-water partition coefficient, dimensionless	8.35×10^{-6}	Environment Agency (2008)
Dermal absorption fraction, dimensionless	0.3	Skowronski <i>et al.</i> (1994)
Diffusion coefficient in air, $\text{m}^2 \text{s}^{-1}$	7.90×10^{-6}	Environment Agency (2008)
Diffusion coefficient in water, $\text{m}^2 \text{s}^{-1}$	6.36×10^{-10}	Environment Agency (2008)
Octanol–water partition coefficient (log), dimensionless	1.48	Environment Agency (2008)
Organic carbon–water partition coefficient (log), $\text{cm}^3 \text{g}^{-1}$	1.92	Environment Agency (2008)
Relative molecular mass, g mol^{-1}	94.11	Environment Agency (2008)
Soil–water partition coefficient, $\text{cm}^3 \text{g}^{-1}$	NA	
Vapour pressure, Pa	11.5	Environment Agency (2008)
Water solubility, mg L^{-1}	84,100 (25°C)	Environment Agency (2008)
Soil-to-dust transport factor, g g^{-1}	0.5	Environment Agency (2009b)
Soil-to-plant concentration factor, mg kg^{-1} FW per mg kg^{-1} DW		
Green vegetable produce	To be modelled	Environment Agency (2009e)
Root vegetable produce	To be modelled	Environment Agency (2009e)
Tuber vegetable produce	To be modelled	Environment Agency (2009e)
Herbaceous fruit produce	To be modelled	Environment Agency (2009e)
Shrub fruit produce	To be modelled	Environment Agency (2009e)
Tree fruit produce	To be modelled	Environment Agency (2009e)

Notes:

DW = dry weight

FW = fresh weight

NA = not applicable (the CLEA model does not require these values in the derivation of assessment criteria for organic chemicals)

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The CLEA Guidance incorporates the following

- 1) *Science Report SC050021/SR2: Human health toxicological assessment of contaminants in soil.*
- 2) *Science Report SC050021/SR3: Updated technical background to the CLEA model.*
- 3) *Science Report SC050021/SR4: CLEA Software (Version 1.04) Handbook.*
- 4) *CLEA Software version 1.04 (2009)*
- 5) *Toxicological reports and SGV technical notes*

The CLEA Guidance can help suitably qualified assessors to estimate the risk that a child or adult may be exposed to a soil concentration on a given site over a long period of exposure that may be a cause for concern to human health. The CLEA Guidance does not cover other types of risk to humans, such as fire, suffocation or explosion, or short-term and acute exposures. Nor does it cover risks to the environment or the pollution of water.

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